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OUR UNDISCOVERED HERITAGE: PAST AND FUTURE PROSPECTS FOR SPECIES-LEVEL BOTANICAL INVENTORY

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ABSTRACT

On-going botanical field exploration and the synthesis of resultant data into species-level plant distribution information in the United States has been handicapped by multiple assumptions: results of such an effort would have little or no pragmatic implication; all necessary work has already been completed, and the resultant information just needs to be compiled within a modern informatics framework; herbarium vouchers are not only already sufficient but become peripheral once label data are captured; further contribution by the systematics community is likewise peripheral, except for a trickle of new species descriptions that can be readily accommodated; species-level field exploration within the United States is neither science nor fundable; and a comprehensive species-level inventory is simply too big a project to tackle. To address these assumptions, a brief account of botanical surveys contemporaneous with topographic mapping efforts of the U.S. Geological Survey is presented, with parallels drawn where possible. Botanical inventory efforts of the University of California at Berkeley are likewise presented, including involvement in Wieslander's Vegetation Type Mapping Project and Bailey and Bailey's project to map the vegetation of Western National Parks. The cumulative result of these and other efforts, however, leave us with an estimated 5% of the national vascular flora still to be described, and distributional information of the known species falling far short of what is needed for informed decision-making. Simple accretion of additional distributional reports is not sufficient, but needs to be based on vouchered reports that have been critically evaluated within taxonomic models by members of the systematics community. The conclusion is therefore that standing assumptions are unjustified, and that a large-scale biodiversity counterpart to the topographic efforts of the U.S. Geological Survey is in fact a realistic and desirable goal.

During this past century, organized field exploration of botanical diversity and the synthesis of resultant data into species-level plant distribution information in the United States have become somewhat passé, at least in scientific realms. At best, earlier cataloguing of species has been transcended by vegetation mapping efforts undertaken by plant ecologists, often completely decoupled from plant systematists who are expected to focus on phylogenetic analyses. As addressed by subsequent papers in this symposium (i.e., Baldwin [2000], Charlet [2000]), both phylogenetic analysis and vegetation mapping represent extremely productive arenas of research, having conservation and land management significance well beyond pure science. The question nevertheless needs to be answered: should the age of species-level botanical surveys indeed be properly relegated to the past, or is there instead not only a legitimate opportunity but a crying need for seriously supported species-level field exploration and the synthesis of resultant information within a scientifically valid framework?

To answer this question, one must first analyze the real and perceived obstacles to species-level botanical inventory in the United States. Prominent among these would be the following assumptions:

- The results of such an effort would have little or no pragmatic implication.
- All necessary work has already been completed, and the resultant information just needs to be compiled within a modern informatics framework.
- Herbarium vouchers are not only already sufficient, but become peripheral once label data are captured.
- Further contribution by the systematics community is likewise peripheral, except for a trickle of new species descriptions which can be readily accommodated by the environmental sciences and informatics communities.
- Species-level plant inventory in the United States is not sufficiently scientific, innovative, or otherwise high-profile to merit funding.
- A comprehensive species-level inventory is simply too big a project to tackle (hence the short-cuts of vegetation mapping, indicator species, umbrella species, etc.)

Just how valid are these assumptions? Are they supported by either the historical record or modern-day realities? And if not valid, what are the implications for such modern-day issues as biodiversity conservation, which relies heavily on comprehensive, accurate distributional information as the basis for critical land-management decisions? The purpose of the current paper is to address these questions, beginning with (and leaning heavily on) the historical context and precedents.

Lessons from the Past

The fate of national surveys. When a modern biologist is presented with the question, 'What newly-established systematic survey of the United States was dealt a serious set-back by a hostile Congress on the grounds of being unrealistically ambitious, too costly and long-lasting, scientifically suspect, of limited (or negative) value, too much power concentrated in a single federal bureaucracy, contrary to the ideals of private property and free-market enterprise, and a threat to western state's rights?' the abortive attempt to establish a National Biological Survey in the early 1990's readily comes to mind. This ambitious proposal, outlined by the National Research Council of the National Academy of Sciences (1993), was a primary target of the heavily conservative 104th Congress's 'Contract with America,' surviving on a significantly diminished scale within the United States Geological Survey (USGS) (Wagner 1999). Although the resultant Biological Resources Division, established in 1996, has certainly generated its share of solid biological research, the discrepancy between the original vision and the eventual outcome left the concept of a full-fledged biodiversity survey of the nation discredited, and many of its proponents disheartened.

What has been forgotten, however, is that the description applies equally well to the founding of that venerable institution, the USGS itself, under the directorship of John Wesley Powell. Although Powell is best known nowadays for his heroic exploration of the Grand Canyon, his biography by Stegner (1953) illuminates clearly the pivotal role that Powell played in the development of land management principles and governmental agencies that went hand-in-hand with the settlement of the western United States. Powell advocated comprehensive topographic mapping of areas being opened for settlement as an essential precursor to rationale land-use planning. He focused particularly on water rights and grazing allocations, recommending Mormon-style cooperative irrigation districts and 2500 acre grazing units (Goetzmann 1966). These proposals, however, were not well received by the majority of Westerners at the time, giving rise to protracted political battles that remain part of our present legacy.

Nevertheless, in spite of vehement opposition to Powell's vision and efforts, the long-term result in the topographic realm was success beyond Powell's most ambitious dream. As noted by Stegner (1953), seven decades after the initiation of the USGS over half of the United States had been topographically mapped, but only about one-fourth on the scale needed for contemporary planning. As a result, in 1953 there were more than two dozen government bureaus engaged wholly or partially in the preparation and printing and use of maps. Stegner also noted that this success resulted in spite of Powell's gross under-estimation of the task (i.e., 24 years at a cost of $18 million), and that even though 'Some members of Congress a little later were ready to bet him that he couldn't do it in a hundred years for a hundred million . . . they ignored what was palpably true, that the maps were worth anything they cost, and more' (p. 280). If a parallel effort had been undertaken for biological mapping over the same span of time, would we now likewise take for granted the worthiness of the effort and value of the results?

The California geological survey. As it happens, various state and federally sponsored surveys that served as precursors to the USGS had generally included a biological component. As a prime example, the California Geological Survey (CGS) of 1860–1873, under the direction of J. D. Whitney, included in its mission 'a full and scientific description of its rocks, fossils, soils, and minerals, and of its botanical and zoological productions, together with specimens of the same, which specimens shall be properly labeled and arranged, and deposited in such place as shall be hereafter provided for that purpose by the legislature' (quoted in Brewster 1909, p. 185). In contrast to the USGS, state surveys in general enjoyed widespread support as 'a hallmark of enlightened state administration, a source of local cultural pride, and the means whereby exploitable resources might be cheaply located and advertised to would-be investors' (Goetzmann 1966, p. 355). The CGS likewise enjoyed public acclaim initially, but popular support quickly dwindled when the anticipated flood of economic benefits did not immediately materialize. As bemoaned by Whitney: 'State officers would be my best friends if I would be their confidential adviser in their interest in claims and stocks, but as it is, I do not know one of them who cares a rye-straw for the work [of the Survey]' (quoted in Leviton and Aldrich 1997, p. 66).

The prolonged decline of the CGS, as a result of political and economic interests independent of scientific value, left Whitney increasingly dispirited and disillusioned. This progression is wonderfully captured in a series of letters from Whitney to his brother, with a political cynicism that still resonates strongly (quoted in Brewster 1909, pp. 264–266):

> 26 February 1868: The prospects of the survey remain as uncertain as ever. Two committees have been at the office and exhibited even more than their usual amount of stupidity and ignorance. Since the Yosemite Valley bill passed over the Governor's veto, I feel so disgusted with California that I can hardly stand it much longer. Still I am running the survey along in a small way at my own expense, waiting to see what the jackasses at Sacramento will do.
>
> 29 March 1868: We have had a nice little time of it in the legislature. The petroleum and other swindlers made a dead set against the survey and

killed it, having malleable material to work with in the Democratic legislature. . . . We were especially unfortunate in having in the Senate . . . a former United States Surveyor General, under whose administration the fraudulent surveys in the southern part of the state were made, and the character of which is being exposed as fast as our work covers the ground. Of course he found against us with all his might.

And finally (pp. 289–290):

19 March 1874: The survey has succumbed to the stupidity and malignity of the legislature, backed by the same characteristics on the part of the Governor. . . . My own feelings are decidedly those of relief at getting the survey off my hands, with no fault of *laches* of my own, for it is *hard work* making a creditable thing of it on a small amount of money. I have always got more curses than coppers out of it.

Also working against the CGS, and as a parallel to Powell, Whitney himself had drastically underestimated the scale, to the extent that it was impossible for him to follow through on what he had originally promised:

I have found out that the State of California is a prodigiously large one. Not that I did not know it before; but now I have a realizing sense of it. It is as big as Great Britain, Ireland, Belgium, Hanover, and Bavaria put together! If I had a complete map of the state, a corps twice as large as I now have, and worked as fast (on the geology only) as the English government surveyors do, I should finish in just 150 years. Having our own maps to make, our labor is tripled; and consequently we shall be through in 450 years or thereabouts.

(quoted in Brewster 1909, pp. 197–198)

With various ups-and-downs and overall dwindling support, the CGS nevertheless struggled along until finally giving up the ghost in 1873. The biological component, however, had been eliminated some years earlier. The initial survey crew included William H. Brewer as both botanist and Whitney's second-in-command. When Brewer departed in 1864 to accept a professorship in Yale, he was never replaced in kind. Instead, Henry N. Bolander was hired on a contract basis, as funding allowed, to do botanical surveys in parts of the state unvisited by Brewer (Jepson 1898; Ertter 2000b). The several thousand specimens accumulated by Brewer, Bolander, and others formed the basis for the first complete flora of California (Brewer et al. 1876; Watson 1880), compiled at Harvard University by Brewer, Asa Gray, and Sereno Watson, with treatments of specific groups (e.g., mosses) provided by an appropriate specialist.

Although the original state legislation mandated that the reports of the CGS be copyrighted and sold for the benefit of the common school fund, no funds were allocated, so that Brewer's efforts took the form of a labor of love:

I received no pay whatever after the closing of my connection with the Survey of California, neither for the time nor the expense in working up results. I spent an aggregate of two years time, a little more rather than less, and over two thousand dollars in cash, besides deducting another one thousand dollars from my salary from college because of time taken out from my work, that is, absence during term time at work on my plants at the Cambridge Herbarium.

(quoted in Farquhar 1930, p. xxiii)

Whitney was eventually able to secure additional State funding for the publication of several Survey reports, but not for botany. Instead, a select group of California's wealthier citizens, including Leland Stanford, provided the necessary funds from their own pockets (Brewer et al. 1876).

The key lesson to be learned from this look at the history of the CGS, and the fate of the biological component in particular, is that termination of support resulted not from completion of the scientific goals, but because of unmet expectations, special interests, and pure politics. We can only wonder what legacy of critical biodiversity information would have accrued if the California Geological Survey had continued to the present, as has been the situation in several other states (e.g., Illinois, New York). Perhaps, as noted by Brewster (1909), the collapse of the CGS was inevitable at the time:

California, in 1860 when the survey began, looked to a future of unlimited growth and prosperity, and cut its coat according to the cloth it expected to own. Its actual lot was flood and drought, and the Civil War. Under these changed conditions, there were many well-intentioned persons who felt that elaborate, hand-colored monographs on birds and land-shells were not the things the young state needed most. As it turned out, the California Survey, on the scale on which Whitney planned it, was distinctly premature. (p. 301)

Valid as Brewster's evaluation may have been to California of the late 19th century, it rings hollow in the face of early 21st century realities. Political and economic interests remain, but one can no longer argue that a full-fledged biological survey of California, as envisioned by Whitney and as called for by the state legislature in 1860, would still be 'premature.'

National biological surveys contemporaneous with the USGS. Federally supported surveys of western lands began with the Lewis and Clark expedition of 1804–1806 and reached a heyday in the mid-1800's with a broad selection of surveys for railroad routes, boundary delimitations, and general exploration. Most of these surveys included a botanical component and are an important part of the historical record. The focus here, however, is on biological surveys that were contemporaneous with the USGS and that could potentially have served as counterparts.

As well described by Goetzmann (1966), the USGS resulted from the coalescence of three competing federally-sponsored surveys in the 1870's: that of Lieutenant George Montague Wheeler, representing the last attempt by the military to hold onto its former domination of western exploration; those led by Ferdinand Vandiveer Hayden under the aegis of the fledgling Interior Department; and the early efforts of Powell himself, backed by a diversity of sources, both private and government, and including the scientific community as represented by the Smithsonian Institution. Each of these three pre-USGS surveys contained a botanical component, with that of Powell's being weakest, and none providing more than the scantiest opportunity for collecting. This can be seen in the report by Townshend Stith Brandegee, whose botanical career began as part of the Hayden expeditions:

> Attached to the division of the San Juan as assistant topographer, as much time as possible was given to the botany of the country through which our work obliged us to pass. Under such circumstances, it was impossible to make a complete botanical collection of the district to our division; therefore no plants were gathered excepting such as seemed to be additions to the flora of Colorado, as published by the Survey in Miscellaneous Publications, No. 4 [Porter & Coulter, 1874]. The collections and notes were almost all made while riding from one topographical station to another. (Brandegee 1876)

J. T. Rothrock, who joined Wheeler's expedition as botanist-surgeon in 1873 (Kelly 1914), not only collected plants for systematic analysis, but also helped initiate a new dimension of botanical survey by addressing economic aspects of the vegetation. Rothrock's reports included a forerunner of a conservation ethic (at least within the context of the time), quotes by Muir, and (similar to Powell) suggestions that governmental involvement might be appropriate: e.g., 'In view . . . of the acknowledged fact that in our older and more densely populated States we have an impending dearth of timber, would not a wise political economy endeavor to obviate such a result in our Western regions? Tree destruction began with us as a necessity, but it has been matured into an instinct' (Rothrock 1878, p. 34). According to Goetzmann (1966), similar attitudes characterized both Whitney and Wheeler, presaging the battles fought by Powell.

George Vasey, who accompanied Powell's 1868 expedition (Canby and Rose 1893), was in 1872 appointed Botanist to the U.S. Department of Agriculture (USDA), which at that time housed the botanical collections that had accumulated from various exploring expeditions. These collections had been in the custody of John Torrey at Columbia College in New York, with additional oversight provided by Asa Gray as a Regent of the Smithsonian Institution. A few years before his death, Torrey relinquished custodianship, and, in lieu of suitable facilities in the Smithsonian building itself, the collections were deposited with the USDA in 1868. They were not turned over to the Smithsonian Institution until 1894, to be merged with a separate plant collection that had been initiated by Lester Ward, paleobotanist for USGS, giving rise to the U.S. National Herbarium (Morton and Stern 1966).

Vasey replaced Charles Christopher Parry, one of the premier field botanists associated with several earlier federally sponsored expeditions (e.g., the Mexican Boundary Survey). The rationale for Parry's abrupt dismissal in 1871 sheds considerable light on the attitudes behind the declining status that descriptive botany and accompanying herbarium specimens had already attained by this time. According to Frederick Watts, Parry's superior as Commissioner of Agriculture, in a letter to Torrey, Gray, Brewer, and D. C. Eaton (reprinted in Gray 1871):

> . . . [N]othing at all had been done by Dr. Parry beyond his attention to the preservation of the herbarium. This Department is designed to render the developments and deductions of science directly available to practice, that farmers and horticulturalists may be benefited by them. The principles of vegetable physiology, their relations to climate, soils, and food of plants, and the diseases of plants, which are principally of fungoid origin, it is clearly the duty of a botanist to investigate. If possible, he should throw some light upon the origin and condition of growth of the lower orders of cryptogamic botany. This is a domain into which I could not discover that Dr. Parry had ever entered, so far as his practical work here gave any indication. The routine operations of a mere herbarium botanist are practically unimportant.

Further prodding by Gray yielded the information that insubordination, at least as perceived by Watts, may have provided the true grounds for dismissal. In any event, Gray's subsequent recommendation helped Vasey get the vacated position, and with 'patient effort' Vasey managed to overcome 'the lack of appreciation of those in high office who thought it a waste of time and money to advance the sciences which wait upon and promote true agriculture' (Canby and Rose 1893, p. 173), and proceeded to build up the collection extensively.

Vasey was joined by Frederick V. Coville in 1888, who was then recruited to participate in a new federally sponsored initiative to survey the biological resources of the nation. Perhaps Coville's inclusion was spurred in part by an 1887 editorial in *Botanical Gazette* (12:197–198), which decried the cessation of federal support for botanical exploration following the coalescence of competing surveys into the USGS: 'Millions have been spent in increasing our knowledge of the other riches of our domain, but the plants have been left to private enterprise . . . a few thousand dollars from an overflowing treasury could be made to yield an ample return in our better knowledge of one of the noblest and (in a public way) most neglected sciences.' As summarized by Coville (1893, p. 1):

> In 1886 and subsequent years appropriation was made by Congress for a study of the geographic distribution of animals, to be conducted by the Division of Ornithology and Mammalogy, United States Department of Agriculture. In the year 1890 the scope of the work was enlarged by an act of Congress so as to include the distribution of plants as well as animals, and in accordance with this provision the writer was temporarily detailed from the Division of Botany as botanist of the Death Valley Expedition, the first of the biological surveys under the new act. The work was planned and conducted under the direction of Dr. C. Hart Merriam, chief of the Division of Ornithology and Mammalogy. The botanical work undertaken by the writer was to collect and identify the plants of the region traversed by the expedition, to collate those data which had reference to the range of species, and to arrange this accumulated material in such form that it would be useful in studying the facts and problems of geographic distribution.

Subsequent appropriations were made annually 'for botanical exploration and the collecting of plants in little known districts of America in connection with the U.S. National Herbarium' (Coville 1890), eventually resulting in the first state floras for Washington (Piper 1906), New Mexico (Wooton and Standley 1915), and Nevada and Utah (Tidestrom 1925), among multiple other publications on the botany of North America and other parts of the world. However, initial support for botanical survey, probably minimal at best, appears to have quickly declined, as evidenced in the correspondence of one collector, John B. Leiberg:

> During the past three summers I have been fortunate enough to obtain a commission from the Dept. of Agri. for field work in the Columbia basin. As the routes are long, one obtains a pretty good field knowledge of many species over a considerable area. For this reason the position is desirable. From a pecuniary standpoint of view it is not. A commission is only given for a limited period of each year and the expense involved in providing transportation and the details of one's outfit absorb from 50% to 80% of the total salary that the commission carries. . . . Whether these explorations will be continued I do not know. So long as there is any money available for field work there seems no good reason why they should not. . . . A great deal of our territory is so difficult and expensive to explore that unless some Gov't aid is afforded we will never know the complete flora of these regions. Sheep and cattle are rapidly destroying the native plants and by the time private explorations reach these regions the flora will have been totally exterminated by such agencies.
>
> (Leiberg to C. V. Piper, 5 July 1896 [printed in *Sage Notes* (Idaho Native Plant Society) 21(4): pp. 6–7])

Piper, to whom this correspondence was addressed, likewise received minimal support for his efforts, with field work 'carried on in chance hours of leisure and in occasional summer vacations' (Coville in Piper 1906, p. 5).

Leiberg's 1895 instructions represented a shift from general floristic survey to a comprehensive overview of topography, climate, timber resources, and aboriginal uses of native plants (Coville in Leiberg 1897, p. 1). The timber focus was tied to the controversial Forest Reserve Act of 1891, which gave the President authority to establish forest reservations from public domain lands. This act was passed in response to the devastation that was being wrought by unregulated exploitation of western resources, as well detailed in Leiberg's report:

> The next and last stage in the destruction of the forests, which is still in active operation, came when the great ore deposits in the Couer d'Alenes [in northern Idaho] were discovered. Thousands of prospectors flocked into the country then, and the forest fires raged in hundreds of localities to clear away the dense growth of timber and shrubs, which very materially interfered with the work of the prospectors seeking mineral-bearing lodes. As the mines began to develop, fuel and timber were needed. The choice parts of the forest were cut into, debris took the place of the green tree, and fire coming later, finished what the axe had spared.
>
> (Leiberg 1897, p. 3)

The resultant Forest Reserves, initially established within the Department of the Interior in 1897, were transferred to the USDA in 1905, and in 1907 were renamed National Forests in order to counter the impression that they had been completely withdrawn from use. The responsible agency was likewise renamed, in 1905, from the Bureau of Forestry to the U.S. Forest Service (McClure and Mack 1999).

During this period the Division of Ornithology and Mammalogy, within which botanical surveys associated with the U.S. National Herbarium had been initiated, also went through several metamorphoses, being renamed the Division of Biological Survey in 1896 and, in 1905, the Bureau of Biological Survey. In 1939 it was furthermore transferred from USDA to the Department of the Interior, and the following year consolidated with the Bureau of Fishes to form the U.S. Fish and Wildlife Service. By this time, however, whatever support might have once existed to undertake a comprehensive botanical inventory at the national level had essentially disappeared.

On the other hand, impetus for scattered species-level inventories, at least for a selection of rare species, was triggered with the passage of a diversity of environmental legislation at both federal and state levels (e.g., Endangered Species Act, California Environmental Quality Act), beginning in the late 1960's. One result has been a flurry of species-level surveys done as part of environmental impact statements, often limited to the target species but sometimes more comprehensive, with quality ranging from superb to dubious. As a broad generality with many exceptions, these have largely resulted in unvouchered species lists scattered throughout the 'gray' literature of environmental documentation, or in the file cabinets of governmental agencies and consulting firms. Efforts to compile this massive accumulation of potentially invaluable distributional information have begun (e.g., CalFlora [www.calflora.org]), though the complications in doing so have proven to be daunting. Furthermore, the majority of these surveys have been largely decoupled from the systematics community who formed the core of earlier botanical survey efforts, and who continue to have primary responsibility for the comprehensive synthesis of floristic information. Various limitations and pitfalls resulting from this decoupling are discussed later in this paper.

Past and Future Role of the University and Jepson Herbaria

The California Geological Survey not only served as a precursor to the USGS and many of the contemporaneous biological survey efforts highlighted in the preceding section, but also set the stage for the long involvement of the University of California at Berkeley (UCB) in botanical surveys of California and the western United States in general. Whitney, as both director of the CGS and chairman for the commission that drafted plans for the future State University (Brewster 1909), claimed that:

> [T]he establishment of the Geological Survey was in fact the first step towards the production of a State University. Without the information to be obtained by that Survey, no thorough instruction was possible on this coast, either in geography, geology, or natural history; for the student of these branches requires to be taught in that which is about him, and with which he is brought into daily contact, as well as that which is distant and only theoretically important.
>
> (quoted in Stadtman 1970, p. 27)

Perhaps because of Whitney's influence (and/or for fear that the collections would otherwise remain at Harvard University, which Whitney had been accused of acting for the benefit of [Brewster 1909]), the 1868 Organic Act establishing the University of California specified that:

> The collections made by the State Geological Survey shall belong to the University, and the Regents shall, in their plans, have in view the early and secure arrangement of the same for the use of the students of the University, so soon as the geological survey shall be completed, and of giving access to the same to the public at large and to visitors from abroad; and shall in every respect, by acts of courtesy and accommodation, encourage the visits of persons of scientific tastes and acquirements from other portions of the United States and of Europe, to California. The said collections shall be arranged by the resident Professors of the University in a building by themselves, which shall be denominated the 'Museum of the University.'
>
> (California Assembly Bill No. 583, Sect. 24)

Tradition has it that an initial set of CGS botanical specimens was received by the University in 1872, thereby establishing the University Herbarium (in fact if not in name), though no records have been located to confirm this (Ertter 2000b).

In any event, there is evidence that in-house collecting activities began within the first few years of the University's existence, as evidenced in a printed report submitted by Joseph LeConte (1875), hired as the first professor of Geology, Natural History and Botany when the University opened its doors: 'In accordance with my promise I hereby make a brief report of the results of the recent excursion made by the University Scientific Party. The party as you know was organized for the purpose of utilizing the Spring recess of a week, in giving some practical instruction in Geology, Lithology, and Surveying; but expected also to make some collections of plants, rocks, fossils, etc., for the Museum.' The party spent a full week to travel from Berkeley to Black Diamond Mines and Mount Diablo and back: 'As our time was very limited we stopped but little until our objective points were reached.' About 150 plants were collected by 'our young botanist' Franklin P. McLean: 'Whether any of these are new or not remains to be determined.' McLean, a graduate of the University's College of Pharmacy in 1875, also accompanied LeConte's expedition to Yosemite in the summer of 1875 and collected elsewhere in California, in the process unfortunately assigning the wrong locality to several collections (Jepson notebooks: Calif. Bot. Expl. II: pp. 99, 118–119, 128, 188).

This early collecting tradition received new impetus with the arrival in 1885 of Edward Lee Greene as the first full-time Professor of Botany, assisted by Marshall Avery Howe and attracting such dedicated students as Willis Linn Jepson and Ivar Tidestrom. In 1891, the Chamisso Botanical Club was organized at the University 'by officers and students interested in botanical work. The promoters of the club had especially in view the collection of material upon which to found local plant-lists' (Jepson 1894, p. 171). Different members staked out territories, in which trespassing by rivals was discouraged, with one exception: 'Professor Greene as the Great Chief was of course free from all restrictions. We had too much to gain from his friendship to object to his hunting on our grounds' (Frederick Theodore Bioletti, quoted in Ewan 1955, p. 35). Tidestrom would go on to be one of the botanists working for the U.S. National Herbarium, whose efforts resulted in the first flora of Utah and Nevada (Tidestrom 1925). Jepson himself remained at Berkeley, amassing the extensive collection that would ultimately be donated to the University as the core of the Jepson Herbarium (Beidleman 2000). Jepson's personal activities were greatly supplemented by the extensive network he cultivated throughout California, ranging from lawyers to farmers to high-school teachers (Ertter 2000c).

Beyond the extensive collecting activities of faculty, staff, students, and others connected with UCB, which followed these early beginnings, there has been a strong tradition of large-scale collaborative survey efforts with various federal and state land management agencies. The most extensive was the Vegetation Type Mapping Project (VTM), with the U.S. Forest Service acting as lead agency (Wieslander 1935). The concept was purportedly inspired by a course taught by Jepson (Jepson et al. 2000). The original scope of the VTM entailed 220 map units (Wieslander 1935), coinciding with topographic quadrangles, but only 23 were published before further activities were disrupted by the outbreak of World War II (Wieslander et al. 1932–1943). In addition to maps, the VTM resulted in over 23,000 vascular plant collections that are now housed in the University Herbarium:

> [The VTM collection] includes many plants in addition to those required for authenticating the maps and sample plots. Very complete field notes accompany each specimen, comprising information as to collector, date, elevation, location, also notes as to size and character of the plant, the slope exposure, the formation in which it grows, and the names of the more common associated species. The primary purpose of the herbarium is to serve as a check upon field identifications, and to afford a permanent record of the plants collected in each quadrangle. Probably its greatest value, however, will lie in the wealth of material from all parts of the region, and in the detailed information, as to the range, habitat, and associated plants that will be available for each species. (Wieslander 1935, p. 142)

The VTM vouchers have been an invaluable addition to the University Herbarium collections, and have been used as types of at least twelve taxa: *Arctostaphylos glutinosa* B. Schreib., *A. morroensis* Wiesl. & Schreib., *A. otayensis* Wiesl. & Schreib., *A. rudis* Jepson & Wiesl., *A. pilosula* Jepson & Wiesl., *A. silvicola* Jeps. & Wiesl., *Ceanothus otayensis* McMinn, *Galium andrewsii* A. Gray var. *gatense* Dempster, *Githopsis pulchella* Vatke subsp. *campestris* Morin, *Helianthemum suffrutescens* B. Schreib., *Melica californica* Scribn. var. *nevadensis* Boyle, and *Sidalcea hickmanii* Greene subsp. *anomala* C. L. Hitchc. Several of these were described by researchers unconnected to the VTM, long after the survey had ended.

As an apparent offshoot of the VTM, and thereby likewise owing a debt to Jepson, a massive effort to map the vegetation of the Western National Parks was initiated by Harold E. Bailey (H. Bailey and V. Bailey 1941; V. Bailey and H. Bailey 1949). As recalled by his wife and coworker, Virginia Long Bailey:

> I met Harold E. Bailey, who had just come up from U.C.L.A., planning to work toward a Ph.D. degree under Lee Bonar. The Ph.D. degree was finally completed in 1935 just prior to the start of the Vegetation Type map Survey of the Western National Parks. During this three-year project (1935–1937, extending into Olympic Nat. Mon. thru 1938 with us) the winter periods were spent in Berkeley and my work with Dr. Jepson was continued part time. . . . I think the summer of 1933 must have been the time that Harold had done some veg. type map work with the Sequoia crew [of the VTM], led by Theodore Plain.
> (V. Bailey to R. Beidleman, 11–20 May 1996)

Mapping activities were conducted by crews recruited from a variety of sources, with participants often going on to higher level positions within the parks and other agencies. As recalled by John Rutter, former Assistant Superintendent of Rocky Mountain National Park:

> I had to quit school to work awhile in 1934. I went to work as a helper in a type map crew for A.E. Wieslander in the California Forest and Range Experiment Station. I was loaned to Yosemite N.P. for 90 days to map much of the Park

north of the Valley. I didn't ever go back to the Forest Service. . . . I knew Harold as a teaching assistant before he became project leader for the type map.

(Rutter to R. Beidleman, 7 November 1996)

Even more than the VTM, the National Park mapping project involved a close collaboration between federal land-management agencies, in this case the U.S. National Park Service, and UCB, taking advantage of depression-relief funding:

The plant collecting activities in which we were involved were in connection with a vegetation type map survey (of the western national parks) carried out under a government sponsored 'Emergency Conservation Works' project under the direction of the western regional office of the Division of Forestry of the National Park Service during a three-year period, 1935–1937. . . . Headquarters was on the University of California campus in Berkeley and an agreement was reached with the University of California herbarium to identify the plant collections. They were to retain a duplicate set of the collections identified and send a list of the identifications to each park area involved. Duplicates should have been left at park headquarters in each case, but if not, then the herbarium was to send a set along with the list of identifications.

(Bailey and Bailey to Wm. M. Lukens, Supt., Chiricahua Nat. Mon., 3 September 1974)

As with the VTM, this productive collaboration was disrupted with the onset of World War II and the end of Emergency Conservation Works funding. Not only was mapping work discontinued, but budget cuts within the University Herbarium precluded further processing of the resultant specimens. Several thousand unidentified, unlabelled, and unmounted specimens languished as backlog until the 1990's, when National Science Foundation funding (BSR-8417804) finally allowed the completion of the University Herbarium's contribution to one of the most exemplary collaborations it has ever been involved in.

One further collaborative survey of California plants took place in the intervening years, involving the UCB Department of Botany, the California Department of Fish and Game, and the U.S. Fish and Wildlife Service. The focus was California's wetland flora, in particular the feeding and resting areas for migratory aquatic birds. Federal funds provided for five year's of intensive field work by a team of assistants working under the direction of Herbert L. Mason, resulting in both the authoritative reference to California's wetland flora (Mason 1957) and thousands of invaluable herbarium specimens deposited in the University Herbarium. This wetland survey, along with the VTM and the Western National Parks mapping effort, serve as exemplary models for comparable undertakings at a time when accurate information on plant distributions has become increasingly critical.

Isn't It Done Yet? or, You Get What You Pay For

The preceding historical accounts highlight scattered examples of state and federally supported biological surveys that were contemporaneous with the development of the USGS, as well as the involvement of the University of California at Berkeley in such activities. In addition to presenting an overview that has not previously been summarized, this synopsis is intended to emphasize the minimal support allocated to species-level botanical surveys during the period that the USGS topographic mapping effort was in full swing, resulting in the full suite of topographic maps that are now taken for granted. This divergence in support undoubtedly was tied to perceived economic importance, with what botanical component there was increasingly shifted to timber and rangeland resources of immediate and obvious economic significance. As a result, species-level inventories became increasingly dependent on scattered individual efforts outside of any organized framework (Ertter 1995, 2000a).

With the advent of endangered species legislation, however, it suddenly became important to have accurate, comprehensive information on past and present distributions of all plants in the United States. Not only does such information serve as the raw data from which rarity status is initially determined, but it also forms the basis on which informed decision-making depends. The negative consequences of basing critical land-management decisions on incomplete or inaccurate species-level distribution information can cut both ways, increasing the risk of misplaced (and expensive) mitigation efforts as well as the unanticipated extinction of overlooked species (Ertter 2000a). In other words, information that had been treated as primarily of peripheral scientific interest suddenly took on significant socioeconomic importance, over which lawsuits have been fought.

Going beyond rare and endangered species, comprehensive distributional information for all plants is increasingly needed for burgeoning restoration efforts. The importance of such for post-fire restoration is described by Charlet (2000), and information on historical distributions of plants has also played a role in formulating restoration goals for the San Francisco Bay (Goals Project, 1999). On an even grander scale, how much might we depend on comprehensive and reliable baseline information on current plant distributions against which to evaluate the predicted impact of global warming?

Given the current importance of comprehensive botanical inventory and plant distribution information, the question quickly arises: did earlier organized survey efforts, as highlighted previously, supplemented by subsequent scattered efforts, leave us with a legacy of the necessary information? As presented in Ertter (2000a), the answer is a resounding 'No!' Nearly 60 vascular plant taxa per year are still being described from North American north of Mexico, at a remarkably steady rate (Hartman and Nelson 1998). Recent discoveries, many by environmental consultants, range from distinctive shrubs along a well-traveled highway (*Neviusia cliftonii* Shevock, Ertter, & D. W. Taylor [1992]) to a new monotypic genus in the largely agricultural San Joaquin Valley (*Twisselmannia californica* Al-Shehbaz [1999]). Not only is an extrapolated five percent of the national flora yet to be described (Taylor in Ertter 2000a), and therefore subject to extinction from ignorance alone, but the level of distributional information on currently known species is well below that needed for informed decision-making. Charlet's work in Nevada, for example, showed that the distribution of conifers, probably the best-mapped of all plants (e.g., Little 1971), was less well-known than had been assumed, with 40% of the conifer-bearing mountain ranges in Nevada harboring at least one more species than had previously been recorded (Charlet 1996, 2000).

Even where historical distribution has been adequately documented, information on current range is often insufficient to determine rarity status, especially for formerly abundant plants that have lost most of their range to development. The once-common *Horkelia cuneata* Lindley subsp. *puberula* (Greene) Keck, for example, was largely eradicated from the Los Angeles basin before anyone even became aware of its plight (Ertter unpublished data). In the opposite direction, the appearance and spread of non-native plants has been historically under-documented, leading to a massive catch-up effort as the economic impact of invasive species has become evident (e.g., the Sierra Nevada Cooperative Yellow Starthistle Mapping and Assessment Project [Yacoub and Schoenig 2001]). In essence, far from the days of field exploration being well behind us, the need for on-going, organized botanical inventory is both urgent and wide-reaching.

How did the present situation come about, where the gap between available floristic information and what is needed for informed decision-making reached the magnitude it has? Some blame can be laid on the systematics community itself, which has been guilty of seriously underestimating the task and overestimating what had already been accomplished (Ertter 2000a). Whitney's introduction to the botanical report of the California Geological Survey (Brewer et al. 1876) is a prime example: 'The total number of species thus included was estimated at two thousand and it was thought that the work of determining and describing them would not occupy more than a year or two.' As previously noted, the work took considerably more than two years, and the final tally of 3500 species was nearly twice the original estimate. Even this, however, was only half the number of vascular plants currently recorded from California (Hickman 1993), and the actual number is a matter of speculation. A parallel is readily seen with Powell's underestimation in carrying out his vision of comprehensive topographic mapping, as noted earlier, in the contrast between initial expectations of the task involved with the actual magnitude of effort required.

An even greater determining factor, however, has been the support (or lack thereof) provided for ongoing species-level botanical inventory by society in general and the scientific community in particular, which controls funding, hiring, and promotions based on what is perceived to be a suitably appropriate scientific undertaking. Watts' negative evaluation of Parry's contribution to science, quoted previously, shows how deep-rooted the resistance to botanical inventory is. Paradoxically, my impression is that society-at-large, far from believing that the generation of species-level distributional information is undeserving of institutional support, instead takes for granted that such support has existed all along, fully parallel to the topographic mapping effort of the USGS. The resultant assumption is that comprehensive species-level distribution maps should *already* be available as needed, for all of the above-cited purposes. Instead, as the preceding historical account demonstrates, as a society we've simply gotten what we've paid for.

The Continuing Role of Voucher Specimens

To the extent that the desirability of comprehensive, reliable, species-level plant distribution information is acknowledged, two somewhat contradictory stances have been adopted: either that all essential information already exists and simply needs to be compiled (the informatics approach); or that such a goal is completely unrealistic, and that various short-cuts must therefore be pursued (the indicator species, gap analysis, and/or vegetation mapping approaches). These alternate approaches are unquestionably valuable, both for their own sakes and as components of a larger undertaking, but none can sufficiently take the place of a comprehensive species-level inventory involving both voucher specimens and the systematic community. The limitations of vegetation mapping divorced from species-level information are addressed admirably elsewhere in this symposium volume (Charlet 2000). Some limitations of the compilation approach have been elegantly analyzed by D. W. Taylor, mostly as work-in-progress.

A key limitation of the compilation approach is its dependence on the adequacy of existing data sources. Figures 1 and 2, generated by Taylor, illustrate the inadequacy of existing documentation of species-level plant distributions in California, based on herbarium specimens in the University

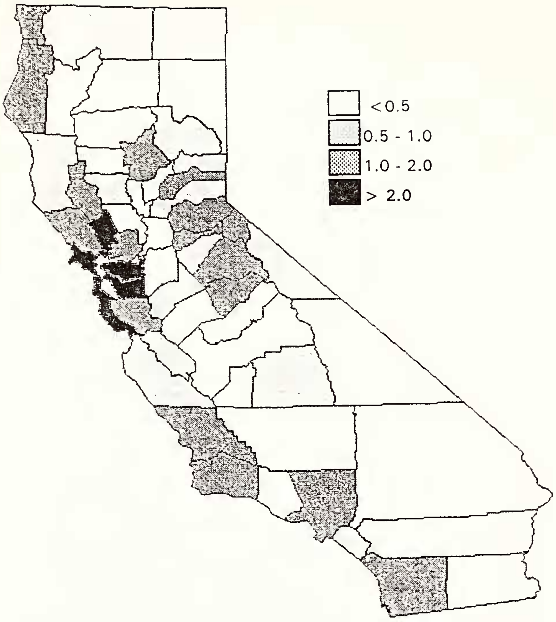

FIG. 1. County map of California showing density distribution of UC/JEPS specimens (sheets/km²), based on a total of over 280,000 sheets.

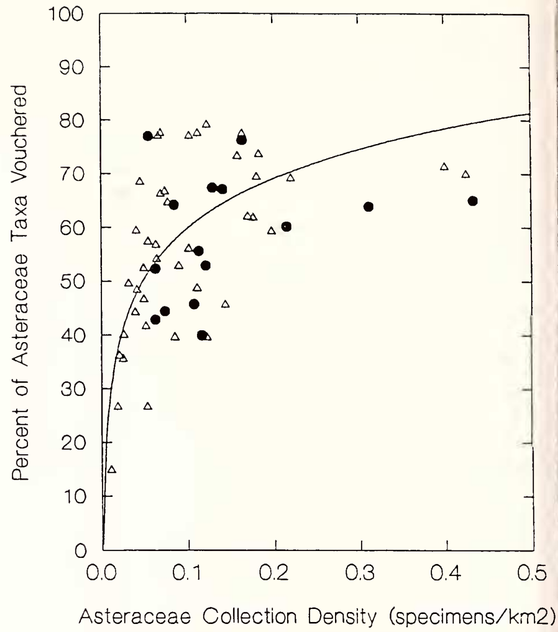

FIG. 2. Relationship between the collection density of Asteraceae (sheets/km²) and the proportion of Asteraceae county records vouchered. Symbols: ● = counties treated by a local flora; △ = other counties. The line shown was selected from amongst a variety of model forms tested based on overall goodness-of-fit ($R^2 = 0.37$, $P < 0.001$). San Francisco County was excluded from the plot (cf. Fig. 1). (D. W. Taylor, unpublished data).

Herbarium (UC) and Jepson Herbarium (JEPS) at the University of California at Berkeley. Although these collections are obviously only a subset of the total number of herbarium specimens in existence available, they are nevertheless representative enough to serve as the basis for initial rough analyses, as presented here. Figure 1, showing collection density per unit area (averaged throughout a county), illustrates the non-uniformity of documentation coverage among the different counties of California. Some of the non-uniformity can be readily explained (e.g., the highest densities in counties surrounding Berkeley; J. P. Tracy's intense collecting efforts in Humboldt County; exchange from herbaria in various southern counties), but the overall pattern of irregular coverage is irrefutable. Furthermore, evidence from other sources underscores how much remains to be documented even in high-density counties. Recent work on the Mount Diablo flora of Contra Costa County (Bowerman and Ertter in press), for example, increased the previously documented flora (Bowerman 1944) by 26%, over half native. Several fully established non-natives were even additions to *The Jepson Manual* (Hickman 1993): e.g., *Dittrichia graveolens* (L.) Greuter and *Trifolium tomentosum* Willk. ex Nyman. In that the recently collected vouchers for the Mount Diablo study have not yet been accessioned, they represent material beyond that included in Taylor's analysis in which Contra Costa County already has one of the highest collection densities.

Figure 2 carries the California-wide analysis a step further, attempting to correlate collections density of each county (*x* axis) with completeness of species documentation (*y* axis), as calculated by comparing predicted occurrence of species of Asteraceae (extrapolated from multiple sources) against the holdings of UC/JEPS. To the extent that this admittedly preliminary analysis is informative, it may be that only 80% of the vascular plants have been documented from even the most heavily collected counties.

Of course, one question that begs to be addressed is, why limit distribution reports to those documented by herbarium vouchers? There is indeed legitimacy in supplementing documented distributions with unvouchered reports (such as the huge number of species lists resulting from various environmental surveys referred to previously), to the extent that an acceptable level of reliability can be determined. Unfortunately, the limitations of determining reliability without a voucher quickly become apparent, underscored by the frequency with which determinations of vouchered occurrences are changed over time for a variety of reasons. Although some changes result from outright initial misidentification, the majority reflect altered taxonomic circumscriptions as our understanding of species boundaries and relationships improves. Examples of both kinds of changes are represented in the updated Mount Diablo flora (Bowerman and Ertter in press), verifiable because of the profuse vouchers cited in the original flora (Bowerman 1944). Both voucher specimens for *Prunus emarginata* (Hook.) Walp. in the 1944 edition, for example, have been reidentified as escaped cultivated species, so *P. emarginata* has been eliminated from the more recent edition. Alternatively, vouchered references in the 1944 edition to *Oenothera hirtella* var. *jonesii,* which had subsequently been split among several taxa (Raven 1969), could be updated to the correct taxa as now circumscribed, something that could not be done with unvouchered citations.

Echoing Wieslander's previously quoted comments on the VTM collections, as well as arguments by Goldblatt et al. (1992) and Ferren et al. (1995), the importance of voucher specimens was clearly emphasized in the report, *A Biological Survey for the Nation,* prepared by the National Research Council of the National Science Foundation (1993, p. 68):

> Collections of specimens are a critical component of the [National Partnership for Biological Survey]. In all but a few well-known taxa, identifications of species must be based on voucher specimens, without which frequent misidentifications are certain to be made. Faulty management decisions are likely to result from incorrect identifications. Collections are repositories for most of what we know about species diversity and are constantly pressed into use for new and often unexpected purposes.

The critical role played by vouchered documentation of species-level distributions, and the limitations of the purely compilation approach to distributional information, is further emphasized when the extent of rejected reports is realized. Although the value of indicating excluded species (i.e., taxa that at one time or another had been included within the group but which are now treated as members of other groups) is well-established in monographic works, the need for comparable lists of excluded or rejected species in floristic works has not generally been appreciated. This has not been a significant problem in monographic floristics, which largely rely on voucher specimens, other than increasing the likelihood of redundant effort anytime the source of the excluded report resurfaces. Keeping track of erroneous or dubious reports becomes critical, however, now that mass compilation of species-level distribution reports from multiple sources has become popular. The magnitude of the potential error can be seen in some floristic examples that have attempted to indicate rejected reports; e.g., 97 in the East Bay flora (Ertter 1997), 66 in the Mount Diablo flora (Bowerman and Ertter in press), equivalent to 6% and 8% respectively of accepted taxa in each flora. Excluded reports include misapplications, confirmed misidentifications, and vouchers with suspect localities, but mostly represent unvouchered reports of dubious nature, often far outside known distributions. Although it has been insufficiently acknowledged, critical evaluation and decision to exclude reported occurrences has in fact been among the primary responsibilities and contributions of the systematics community to species-level distributional informatics.

'Organized' Floristics and the Systematics Community

The significance of critical evaluation by the systematics community stands as a key distinction between the compilation approach to biodiversity informatics, whether electronic or printed, and that employed in established floristics, in which the contents are carefully evaluated, filtered, and synthesized. This distinction underlies Jepson's characterization of compiled, accreted, and organized floristic works, expressed in a recently unearthed letter to Wieslander (3 April 1939, JEPS archives):

> There are three kinds of manuals. First, a manual that is compiled. Second, a manual that is accreted. Third, a manual that is organized. A compiled manual, for example, is such as Coulter's [1885] Manual of the Rocky Mountain Flora (not Nelson's [Coulter and Nelson 1909], but Coulter's). Taken wholly from the literature, nothing is left out, nothing omitted. It is philosophically speaking, perfect and complete. But no real botanist, I think, ever looked within its pages. It is to him useless. . . . Then there is the manual that is accreted. In this case everything is put in, not only from books but also from plants. It, too, leaves nothing out. It adds everything that comes along, both from plants and the literature. It is, also, philosophically speaking, perfect and complete. And, finally, there is the Manual that is organized. My Manual of Botany [Jepson 1923–1925] is organized. It is not perfect nor complete, nor can ever be in a thousand years. The whole treatise is, however, organized into a single unit, every part depending and related and associated with every other part. And it is made up basically from research on plants.'

Jepson's concept of an 'organized' floristic work, with 'every part depending and related and associated with every other part,' is equivalent to the argument in Ertter (2000a) that floras and other kinds of taxonomic treatments are best understood as complex models, encompassing multiple units whose exact identities depend on their relation to other units within the larger context. A prime example is provided by Fig. 3, contrasting four alternate taxonomic models that had been developed to circumscribe taxa within the *Juncus triformis* complex. Although this type of situation has sometimes been disparaged as evidence of the systematic community's purported inability to agree on standards,

COMPARATIVE MODELS OF JUNCUS TRIFORMIS COMPLEX

pre-Hermann	Hermann, 1948	Cronquist, 1977	Ertter, 1986
J. triformis var. stylosus	J. triformis	(not addressed)	J. triformis
	J. megaspermus		
	J. leiospermus		J. leiospermus var. leiospermus
			var. ahartii
J. triformis var. brachystylus	J. kelloggii	J. kelloggii	J. kelloggii
			J. luciensis
			J. tiehmii
	J. capillaris		J. capillaris
J. triformis var. uniflorus	J. bryoides		J. bryoides
	J. uncialis		J. uncialis
	J. hemindytus		J. hemidentyus var. hemiendytus
	J. abjectus		var. abjectus

FIG. 3. Comparison of four taxonomic models (monographic treatments) of the *Juncus triformis* complex. Note in particular the dramatically different circumscriptions of *J. kelloggii* between models.

it is actually a straight-forward case of science in action, with earlier hypotheses and models giving way to new ones in the face of additional evidence. In this particular example, Cronquist (1977) hypothesized that the series of species proposed by Hermann (1948) did not meet the accepted criteria for recognition as distinct species, but rather 'appear to be mere technical variants, often locally constant as in self-pollinated groups in other genera, but with widely overlapping ranges and similar habitat requirements.' In that Cronquist himself was aware of the limited evidence on which his model was based, he encouraged one of his students to put it to the test and was fully accepting of the alternate model that resulted (Ertter 1986), which was based on five years of focused field work, common garden studies, chromosome counts, and seed coat micromorphology. The importance of this particular example in the present context is to illustrate the pitfalls associated with attempts to deal with taxonomic units as free-standing entities divorced from a specific model, as is generally the case in mass compilations. For better or worse, the nomenclatural system adopted by the international systematics community ties the name to a type specimen, not to a circumscription. As a result, the binomial *Juncus kelloggii* Engelm., rather than serving as a unique identifier, can code for three very different entities, depending on whether it is in the context of Hermann's, Cronquist's, or Ertter's model. Compilation efforts that are unable to take this into consideration will inevitably end up generating the most inclusive circumscription (e.g., that of Cronquist) even if this is not the currently accepted circumscription. This can be seen, for example, in the distribution map generated for *J. kelloggii* in the PLANTS database (http://plants.usda.gov:80/plants/), which shows a range significantly larger than the documented range published in 1986.

Another example illustrating the nature of an 'organized' taxonomic work is provided by the recent description of *Deinandra bacigalupii* B. G. Baldwin (1999b), based on what had previously been treated as a disjunct northern population of *Hemizonia increscens* (D. D. Keck) Tanowitz subsp. *increscens* (e.g., Tanowitz 1982). Not only did publication of this new species provide impetus for Baldwin to publish his emerging generic realignment of tarweeds that had resulted from morphological and molecular phylogenetic analysis (Baldwin 1999a), but publication of *D. bacigalupii* also created a new circumscription of *Hemizonia/Deinandra increscens*. As a result, *D. bacigalupii* cannot simply be added to existing floristic treatments (e.g., Hickman 1993) without simultaneously modifying the description and distribution of *D. increscens* to reflect its reduced circumscription.

The purpose of the preceding paragraphs is to clarify that critical analysis by members of the systematics community, rather than being peripheral, is an essential component of on-going botanical inventory. This is by no means intended to downplay the equally critical involvement of agency biologists, environmental consultants, and avocational enthusiasts, who are in fact currently responsible for generating the bulk of new field-gathered information (Ertter 1995, 2000a). The point is that our modeling of biodiversity is still very much a work-in-progress, such that even the seemingly mundane aspects of plant distribution information are often clues to the undescribed 5% of the North American flora, or to the 'cryptic' diversity that is also a critical component of biodiversity (Baldwin 2000). As one example, the revision of the Mount Diablo flora (Bowerman and Ertter in press), as localized as it was, nevertheless involved numerous interactions with taxonomic specialists to address discrepancies between local variation (i.e., plants that 'hadn't read the book') and treatments in *The Jepson Manual* (Hickman 1993), often resulting in changes to the latter. This is in part what Jepson (cited above) meant by a flora 'organized into a single unit, every part depending and related and associated with every other part,' and what he expanded on in the same letter:

> One of my students opened a bundle of plants [in my collection] and exclaimed: 'Why, Dr. Jepson, here are species new to California from the eastern Mohave borders collected by yourself. Why did you not put them in the Manual?' I had to explain that these were critical species which would have taken a long time to determine; and, even after determination, would require a long time for organization into the manuscript. It was not possible to delay the Manual further. In his inexperience the student imagined species could be added just like adding another stick to a pile of cordwood. He had no conception of the hundreds of comparisons involving detailed analysis that must be made in the case of every species added to a systematic account. Even botanists in general have no notion of the mass of work involved in a large systematic treatise.

Looking Ahead: The Harvest to Come

Given the preceding discussion on the historical and current status of species-level botanical inventory in the United States, it is evident that most of the perceived obstacles to on-going efforts are based on false assumptions. Instead:

- The results of such efforts have significant pragmatic implication and potential economic impact, primarily as a critical component of informed land-management decision-making. As a result, properly done survey efforts prove their worth in the long run and have even received significant support from far-sighted private donors on that account (e.g., Stanford's support of the California Geological Survey).
- Federal- and state-funded survey efforts were terminated by politics, special interests, and misconceptions, not because the scientific goals were completed or unimportant.
- The essential fieldwork and critical taxonomic evaluations therefore remain far from finished, and can by no means be offset by simple compilation of existing data, even within a modern informatics framework.
- Herbarium vouchers remain an integral part of scientific documentation, with many more needed to document species-level distributions comprehensively and reliably.
- On-going involvement of the systematics community is likewise integral, not only to address the numerous undescribed species (an estimated 5% of the North American vascular flora) but to ensure that the resultant informatics framework is fully 'organized.'

This leaves the following two assumptions:

- Species-level inventory within the United States is not sufficiently scientific, innovative, or otherwise high-profile to merit funding.
- Comprehensive species-level inventory is simply too big a project to tackle (hence the short-cuts of vegetation mapping, gap analysis, indicator species, umbrella species, etc.)

The first assumption appears to be deeply rooted, at least within the American academic community, such that floristic work has long since fallen out of favor as a suitable topic for graduate work, in spite of Jepson's lifelong efforts to develop floristics as sound science. In Europe, on the other hand, an entire field of chorology has developed around a Committee for Mapping the Flora of Europe, given a recent boost by advances in electronic approaches (e.g., Lahti and Lampinen 1999). This touches on the irony of the exploding prestige and popularity of geographic information systems, often taking place at the same institutions that scorn floristic work by systematists. Most efforts (and funds) to develop essential plant distribution information layers, however, are completely decoupled from the systematics community, relying instead on compilation approaches, with the resultant pitfalls and shortcomings that have been discussed.

Of course, biodiversity informatics as a whole is a favored topic, including within the systematics community itself, spawning a veritable alphabet soup of acronyms at state, federal, and international levels (e.g., as highlighted in ASC Newsletter 28[5], October 2000). At present, however, support for these efforts has been largely directed thus far to massive compilations, perhaps in fact the realistic and appropriate starting points in an absolutely essential and long-overdue undertaking. Existing projects nevertheless appear to be a far cry from fully involving and providing the concomitant support for the systematics community at large, consisting of the multitude of field collectors and monographers who generate the raw data, critically evaluate the results, and synthesize the taxonomic models on which bioinformatics depends.

Complementing such umbrella approaches to bioinformatics, there are a diversity of innovative approaches that could be capitalized on to increase the availability and reliability of new species-level plant distribution data. Charlet (2000), for example, argues for the coupling of documented species-level information with vegetation mapping. One also wonders how far various funds currently being allocated for studies on individually targeted rare or invasive species could go towards comprehensive mapping of all plant species in an area, minimizing the need for redundant surveys over the same ground when yet one more species becomes of interest. A parallel exists with Jepson's advice to Wieslander to expand his proposed mapping effort beyond economically important woody species, on the grounds that 'New economic aspects developed so rapidly that it was proven repeatedly that an economic map was and must be from its nature transient and insufficient' (Jepson et al. 2000). If this advice had been followed from the beginning, a 'considerable appropriation' could have been saved that was subsequently needed to re-map much of the area already covered.

Tapping into the private sector, Ferren et al. (1995) note that the bulk of undocumented (and under-reported) field observations in the United States currently result from legally required environmental assessments prior to development. However:

> Without vouchers deposited in institutional herbaria, the scientific and even legal credibility of these reports is suspect at best, and their long-term value is minimal in spite of the large sums of money spent in producing the documents. In southern California, it is not uncommon for approximately $1 million to be spent for a specific plan and associated [environmental impact review] for larger development projects. . . . For a little extra money, a much more worthwhile review effort could be undertaken. A client's money would be more wisely spent if vouchers were collected and deposited in a formal herbarium than if the environmental review was not documented professionally . . . since the overall budgets for environmental review studies and documents are substantial, it would take only a modest addition to the budget to cover the costs of collecting and depositing voucher specimens.
> (pp. 198, 202)

Beyond and above these and other innovative ways to increase support for on-going botanical inventory, the most fundamental requirement is a change in our understanding of the situation. Rather than being intimidated by the scope of the challenge, I propose that we have not been thinking big enough! We do not have to justify the initiation of a Big Science project; rather, we need to acknowledge that this is exactly what the systematics community has been doing for the last 250 years: a massive international collaboration to model species-level biodiversity, including distribution, that will remain a work-in-progress for decades, perhaps centuries, to come. We are in this for the long run; the challenge now is to assemble the scattered pieces together in a new collaborative framework, combining the best of the systematics and informatics communities, governmental agencies, conservation organizations, avocational enthusiasts, and private landowners, all within a coordinated, mutually profitable, scientifically valid framework.

If this seems daunting, recall again the seemingly impossible challenge faced by Powell in getting the USGS off the ground, and its subsequent vindication beyond his wildest dreams. In his 1886 defense of the USGS (quoted in Stegner 1953, p. 289), Powell provided this stirring testimony:

> If the work thus begun can be continued through the labors of this Commission, and all of the scientific operations of the Government placed under efficient and proper control, scientific research will be established in America upon such a basis that the best and greatest results will accrue there from. The harvest that comes from well-directed and thorough scientific research has no fleeting value, but abides through the years, as the greatest agency for the welfare of mankind.

What would we have now if a true biological survey had existed parallel to the USGS for the last hundred years? What might the next hundred years' harvest be?

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